Playa basin fills near the Pantex Plant — stratigraphic and geomorphic analysis

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Introduction

Playa basins on the Southern High Plains pond water and focus recharge to the Ogallala aquifer. Cores of the sedimentary fills of six of these basins near the Pantex Plant, northeast of Amarillo, have been examined to identify (1) the types of sediments beneath the floors of playa lakes, (2) the relative permeabilities of these sediments, (3) the geometries of playa lake clays and interbedded and interfingering facies, and (4) potential flow paths through the clays. This report focuses on core data rather than exposures because (1) core recovery was excellent, whereas most exposures have been degraded, (2) cores penetrate to greater depths than most exposures, (3) playas cored are close to the Pantex Plant, and (4) core data can be integrated with hydrologic and geochemical test results.

Basin sediments have been examined by drilling 30-m-deep hollow-stem auger cores in a suite of playas and corresponding interplaya areas in a variety of geomorphic settings adjacent to the Pantex Plant (Fig. 1). To date, 41 cores totaling 766 m (2513 ft) of section from six playa basins adjacent to the Pantex Plant have been collected (Table 1).

Playa basins were selected to examine a spectrum of geomorphologic characteristics and flooding histories. Playas examined are: (1) Seven Mile Basin located south of US 60 south of the Pantex Plant; (2) Wink playa basin located outside the west gate of the Pantex Plant; (3) TDCJ playa north of Pantex Lake; (4) Koesjan playa west of Pantex playa 5 , (5) E. Vance playa, east of the east gate of the PantexPlant, and (6) Finley playa in Armstrong County (Fig. 1). Seven Mile Basin is a large basin with a playa that has not been flooded during the past year. Wink, Koesjan, and TDCJ playas are average size playa basins with lakes that were flooded above the rim during the late summer of 1992, but playa lake levels dropped during the winter of 1993 and permitted coring of playa sediments. The E. Vance playa is in a composite of two basins and the Finley playa is in a shallow basin; both have been mostly dry during 1992 -1993.

Playa Basin Geometry

Playa basins include the drainage area of the playa. Upland areas that form the drainage divides between basins have little topographic relief and conform to the gentle southeastward slope of the Southern High Plains. The upland surfaces are characterized by Pullman or Estacado soils. Playa basin slopes are characterized by a variety of slope soils, and small drainages. Slopes of playa basins are generally steep on the northeast side of the playa lake and gentle toward the south. The annulus or rim of the playa is marked by a break in slope that defines the normal high water mark of the playa lake. The floor of the playa lake is nearly flat, and is characterized by dark Randall clay soils.

Facies classification

Based on examination of the cores from six playas, a facies classification for playa basin sediments has been developed (Fig 2). Facies include: (1) gray and red lacustrine clays, (2) lacustrine/eolian sand beds, (3) clays with interbedded or admixed sand laminae, (4) poorly sorted lacustrine delta deposits (5) upland and basin slope "typical" Blackwater Draw clayey silt with buried soil horizons, and (6) lower Blackwater Draw fine-medium sand.

Lacustrine clay

Gray clay (5Y2/1 to 5Y7/1) was deposited in ephemeral lakes similar to modern playa lakes. Clay is massive to faintly laminated, plastic at the surface, and becomes stiff at depth. Small pelecypod valves preserved within the clay and drab colors extending downward from clay beds demonstrate ponding. Soil slickensides, deep clay-filled cracks, root tubules within the clayey beds, and destruction of depositional layering by biogenic and soil processes indicate desiccation and exposure of the lake floor. Red-brown (5YR 5/6) colors in clays may indicate conditions of less effective reduction in the lake environment. Fracture surfaces within firm clay are pigmented by iron and manganese oxides and indicate that fractures have transmitted fluids.

Lacustrine/eolian sand

Well-sorted sand layers within the lake sediments are interpreted as the product of episodic migration of sand sheets across the playa. Many sand layers are only a few millimeters thick, suggesting that they formed when eolian sand adhered to the top of the damp clay while the overlying dry sand was deflated and removed from the basin. In other parts of the facies tract, sand beds are 10 to 30 cm (4 to 12 inches) thick. The preservation of discrete sand beds depends on the intensity of pedogenic modification of the lacustrine sediments. Where pedogenesis and or bioturbation have been intense, sand and clays have been mixed.

Lacustrine deltas (heterogeneous sand, silt, clay, and caliche pebbles)

Laterally and vertically heterogeneous interbedded sand, silt, clay, and caliche pebbles that occur as thin units within the lacustrine sediments are interpreted as parts of delta complexes formed where draws discharged into playa lakes. Minimal soil formation in many delta deposits indicates relatively rapid deposition during progradation. Sediments in delta deposits exhibit variable red brown and gray colors, indicating differences in the oxidation state of iron oxides associated with clays.

Upland accretionary eolian facies

The typical upland facies of Blackwater Draw Formation is characterized by red-brown (5YR5/6) clayey silt with abundant root casts, well-developed soil peds, local distinct soil horizons (soil carbonate and illuviated clay concentrations), and abundant pedogenic carbonate nodules. Variation in clay content appears to reflect soil processes.

Iron oxide, manganese, clay, and calcite mineralization is common on root tubules and ped surfaces and indicate places where water movement has occurred.

Lower Blackwater Draw Formation medium sand

A thick unit of moderately well sorted, poorly consolidated fine to medium sand has been encountered in the lower part (approximately 15 m (50 ft) below lake level) of the Blackwater Draw section beneath upland and playas in all the boreholes that penetrate deep enough. This unit is generally red brown (5YR4/4), with local bleached or reduced zones colors (5YR 7/2) within it. Vertical fractures marked by discoloration are common in the lower Blackwater Draw sands. Fractures in red sands are characteristically light colored, and those within light sandstone beds are typically stained red, indicating that they have transmitted oxidizing or reducing fluids from overlying layers. Carbonate contents of the lower Blackwater Draw sands are generally low and laterally variable.

Stratigraphic relationships

The core data has been used to prepare cross sections through each of the playas. A number of conclusions about the geometry of the sediments beneath the playas and the evolution of playa lakes can be drawn from these cross sections. Lacustrine sediments beneath the playa lakes are 20 m (60 ft) thick in Seven Mile Basin, 15 m (50 ft) thick at the TDCJ playa, and 7 m (25 ft) thick at the Finley playa. Lacustrine sediments were deposited in Pleistocene and/or Holocene ephemeral playa lakes that existed in the same locations as modern playas and include gray clay, fine grained, well sorted eolian sand partings and beds, pedogenically modified, admixed, and partly oxidized admixed clay and sand, and lacustrine delta complexes. The age and formal stratigraphic nomenclature for these lake sediments have not yet been determined. Lacustrine sediments are laterally and vertically heterogeneous and demonstrate the need for collection of suites of samples of playa sediments and associated waters. The fills of these three playa basins are described below.

Seven Mile Basin

The Seven Mile Basin transect extends from the south margin of the basin into the floor of the playa, then turns east (Fig. 3). Seven Mile Basin lacustrine sediments were cored on the slopes of the playa basin, 1.5 to 3 m (5 to 10 ft) above modern lake levels, indicating that the lake has formerly or episodically been much larger, filling most of the large depression that forms Seven Mile Basin (Fig. 4). Seven Mile Basin lacustrine sediments interfinger with alluvial or slope wash sediments on the south margin and contain small scale sediment-filled faults, demonstrating that the topography was similar to the present topography during the late Pleistocene/Holocene. The poorly sorted, course grained alluvial sediments above lake level may be important in the hydrologic behavior of the playa basin in that they may limit the surface flow from upland areas that reached the playa lake. .

Lacustrine sediments in Seven Mile Basin show a systematic vertical evolution. The lower half of the lacustrine section contains lake sediments with a strong pedogenic overprint, indicating prolonged exposure and soil development alternating with flooding of the playa. Most of the upper half contains abundant sand partings and interbeds. Pedogenic overprint is minor. During deposition of this unit, dunes or eolian sand sheets migrated across the playa lake floor when the lake was dry, but the dry episodes were not prolonged enough to develop strong soil textures. The upper 1 to 2 m (3 to-6 ft) of lacustrine clay sediment contains no sand beds and minimal soil textures, although there are deep, clay-filled healed cracks observed in the clay. This systematic variation of textures may indicating an evolution of the playa lakes from originally flooded for relatively short or infrequent episodes (strongly ephemeral conditions) to the present when they are relatively frequently flooded or flooded for long times (least ephemeral conditions). It is hypothesized that this evolution may be related to decreasing leakiness through time of the playa lake as low permeability lacustrine sediments accumulated.

TDCJ playa basin

A transect across the southern part of the TDCJ playa is shown (Fig 5 and 6). TDCJ playa sediments in the southern part of the playa lake contain abundant deltaic deposits, demonstrating that the ephemeral streams which have deposited deltas at the shore of the present playa lake (fig. 5) have been episodically active during accumulation of lake sediments. A core recently drilled near the center of the TDCJ playa has fewer deltaic deposits and more dark clay than those on the southern part of the playa. TDCJ playa basin sediments record several episodes where the playa lake was more extensive to the south and east than present, and several episodes where the playa lake was smaller or confined to the northern part of the basin, and red-brown silty clay of the upland facies of the Blackwater Draw accumulated in the area occupied by the present playa lake. These relationships are significant because they demonstrate the temporal equivalence of lacustrine and upland sedimentation.

Finley playa basin

The Finley playa is an example of a small, shallow playa basin (Fig. 7). The playa fill has more sand beds in the central part of the playa than other playa sections, and the lacustrine section is thinner (Fig. 8). Core density is insufficient to demonstrate the nature of the contact between lacustrine units and upland Blackwater Draw facies.

The sandy facies of the lower part of the Blackwater Draw Formation is recognized in all the cores that penetrate to sufficient depth. This sand lies both beneath playa lakes and uplands and therefor may play a role in the downward movement of water from the playas. Its thickness varies from 30 to 40 feet in the playa basins. The top of the sand facies rises in elevation from beneath the playa to interplaya areas, suggesting that playa basin topography is at least partly inherited from Pleistocene topography. The top of the sand facies is more than 50 feet higher in upland areas south of Seven Mile Basin than it is on the basin floor. This observation fits well with the dips on the mid-Ogallala and base of the Ogallala horizons imaged on Seven Mile Basin seismic sections (J. Paine, in prep.). In other locations, the lower Blackwater Draw sand is at least 10 to 15 feet higher outside the playa basin than beneath the playa floor. The lower Blackwater Draw sands beneath the playa floors locally contain thin red clay beds, which are interpreted as older lake deposits and may indicate older development of the playa basin topography.

Conclusions

In summary, these playa basins accumulated heterogeneous sediments through the Pleistocene and Holocene. Vertical heterogeneities resulting from changes in sediment supply, lake expansion and contraction, delta progradation, and variation in the intensity of soil development document climatic fluctuations. Lateral heterogeneities reflect the asymmetry of playa basins, localized sediment input, and variation in the amounts and types of reworking. The playa basins studied developed during the early or midddle part of Blackwater Draw sedimentation. Since that time, playa lake sedimentation and upland eolian accumulation have been in dynamic equilibrium so that the upland/basin geometry has been maintained.

Complex patterns of clay oxidation and reduction and calcite precipitation and dissolution document the interaction between ground water and sediments in playa sediments and in the lower medium sand unit. Recharge to the perched and Ogallala aquifers may be influenced by areas of increased permeability such as mineralized fractures or eolian sand layers within the lacustrine clays, lacustrine delta facies, or upland silty loam facies interfingering with lacustrine clays. Hydrologic testing will be designed to determine the extent to which these features serve as preferential pathways for recharge of surface waters.

These data will be used to develop a genetic model for evolution of playa basins in order to predict geometries of permeable strata in different geomorphic settings. A classification of playa types based geomorphology and sediment fill may be able to predict which playas are most effective in recharging the Ogallala aquifer.

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Jacquot, L. J.,Geiger, L. C, Chance B. R., Woods, V. D., Leath, D. A., and Imke, L. C., 1961, Soils Survey, Armstrong County Texas, United States Department of Agriculture Soil Conservation Service, Series 1961, No. 20, 80 p.

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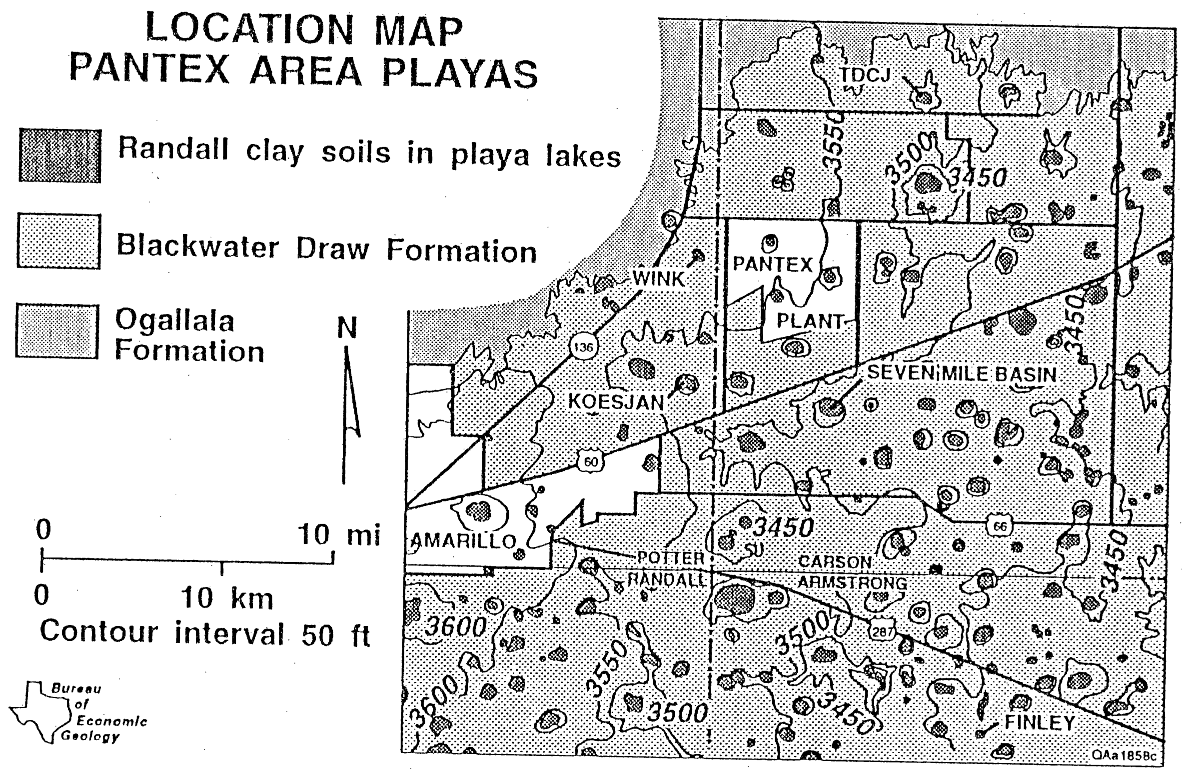

Figure 1. Location map showing the investigated playas in the area of the Pantex plant.

Modified from Eifler, 1981.

PLAYA BASIN FACIES

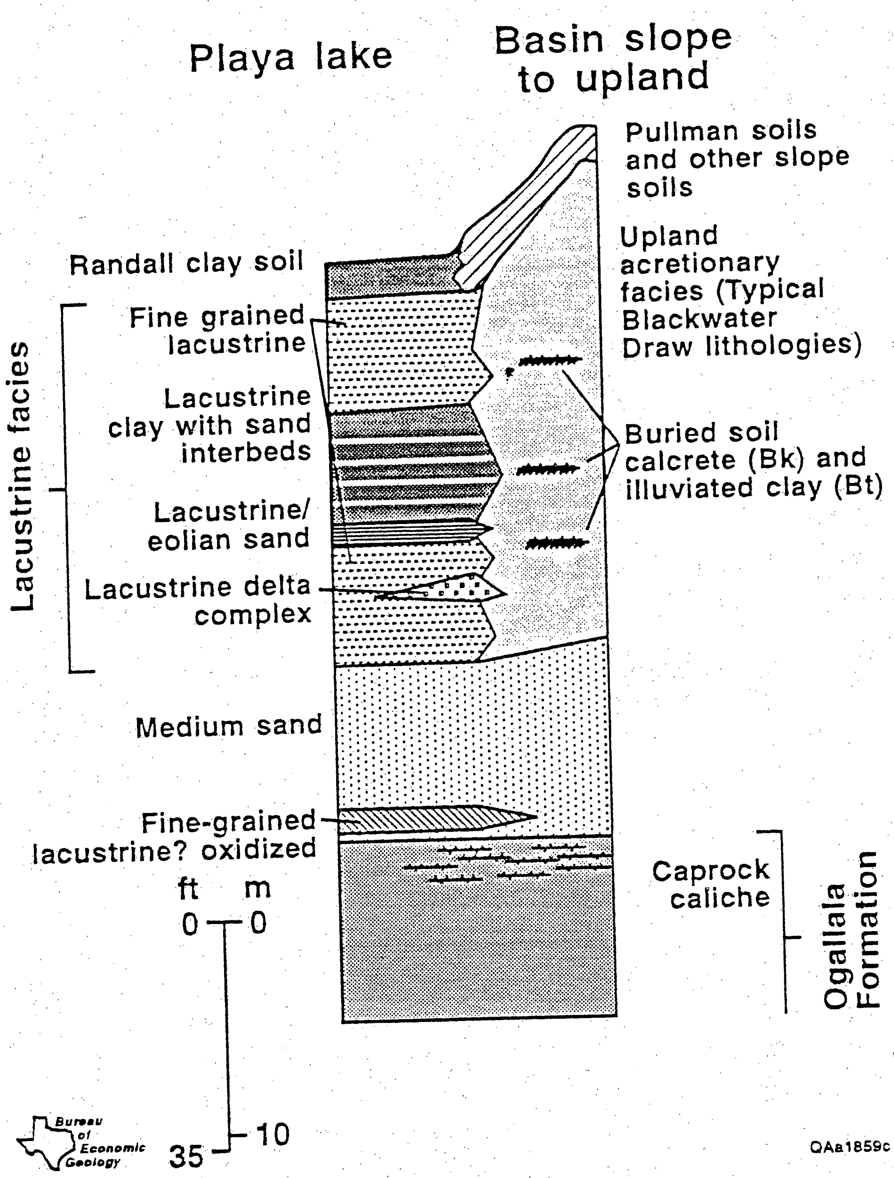

Figure 2. Generalized playa stratigraphic section, listing major facies.

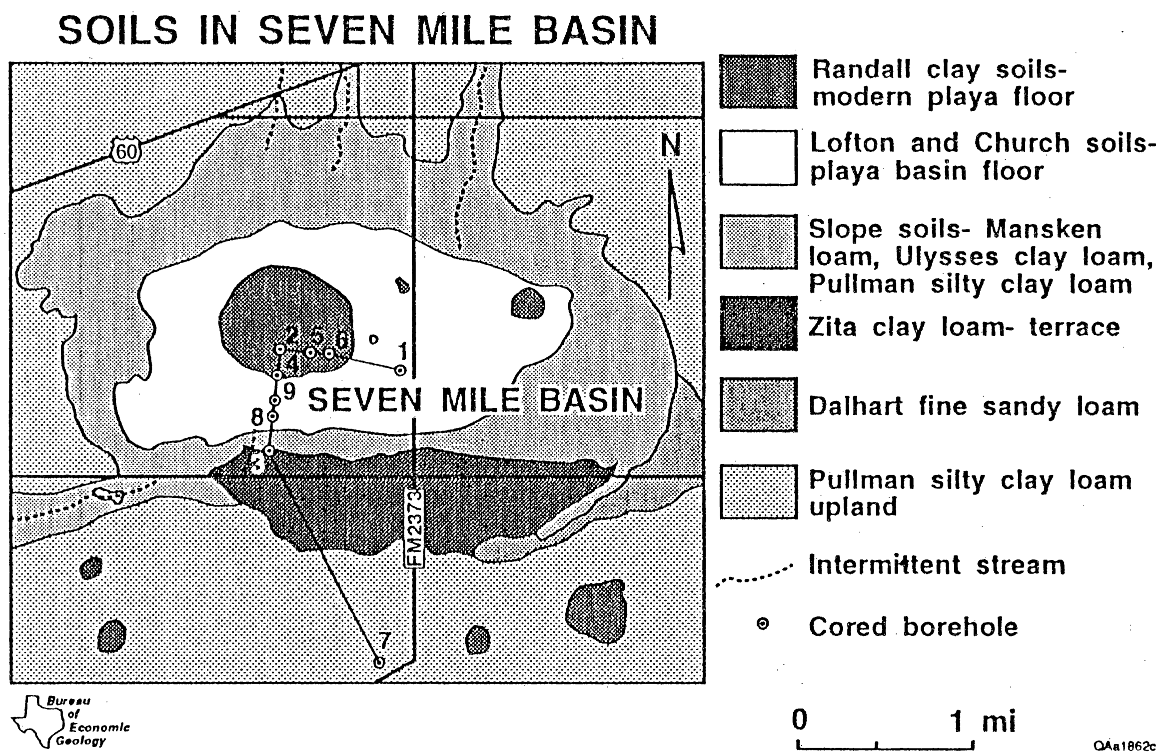

Figure 3. Soils map of Seven Mile Basin (modified from Jacquot, 1959), showing borehole locations.

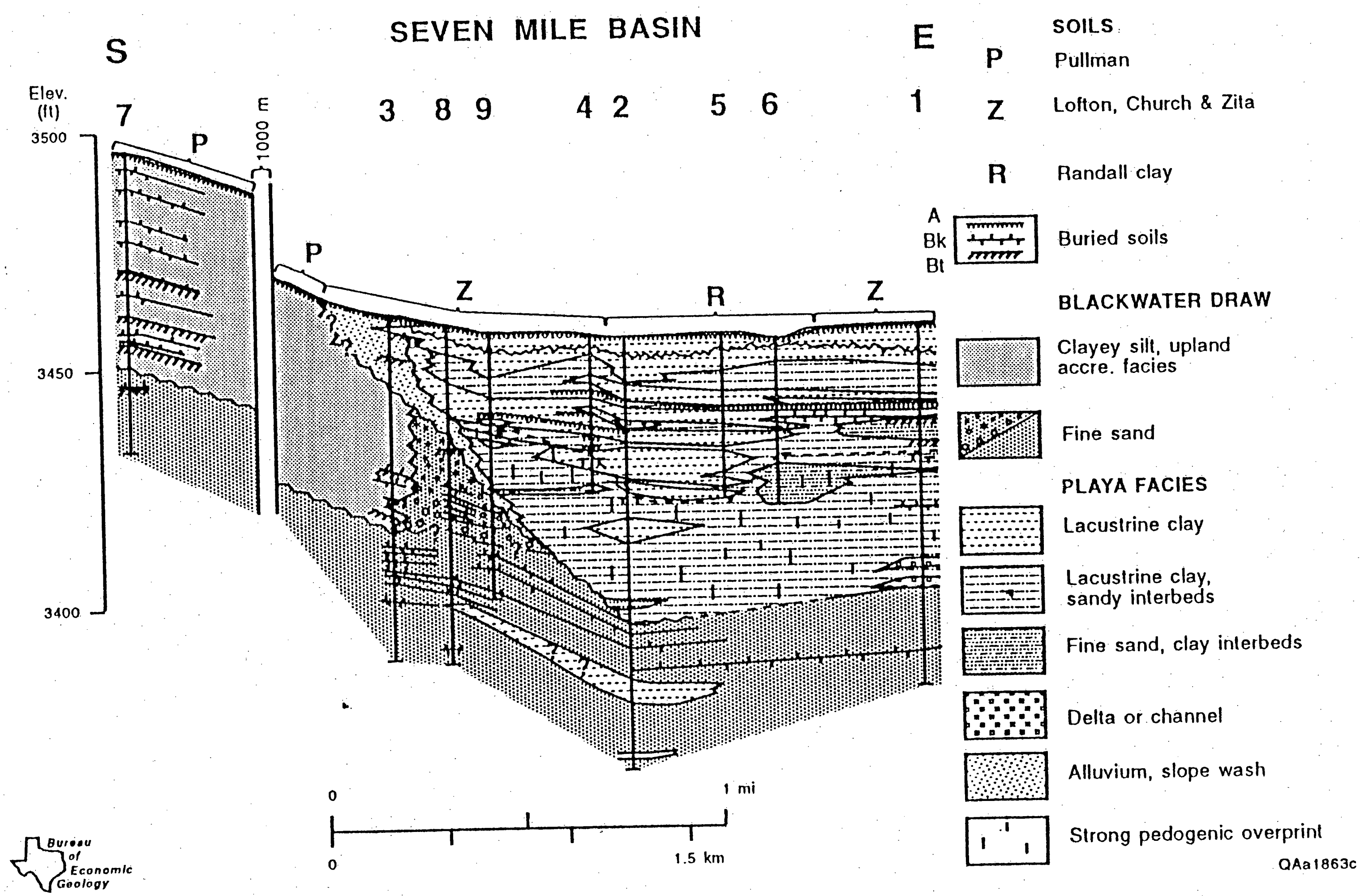

Figure 4. Stratigraphic section across Seven Mile Basin. The Randall clay soil (R) marks the floor of the modern playa lake. The floor of the entire basin has accumulated lake sediments in the past.

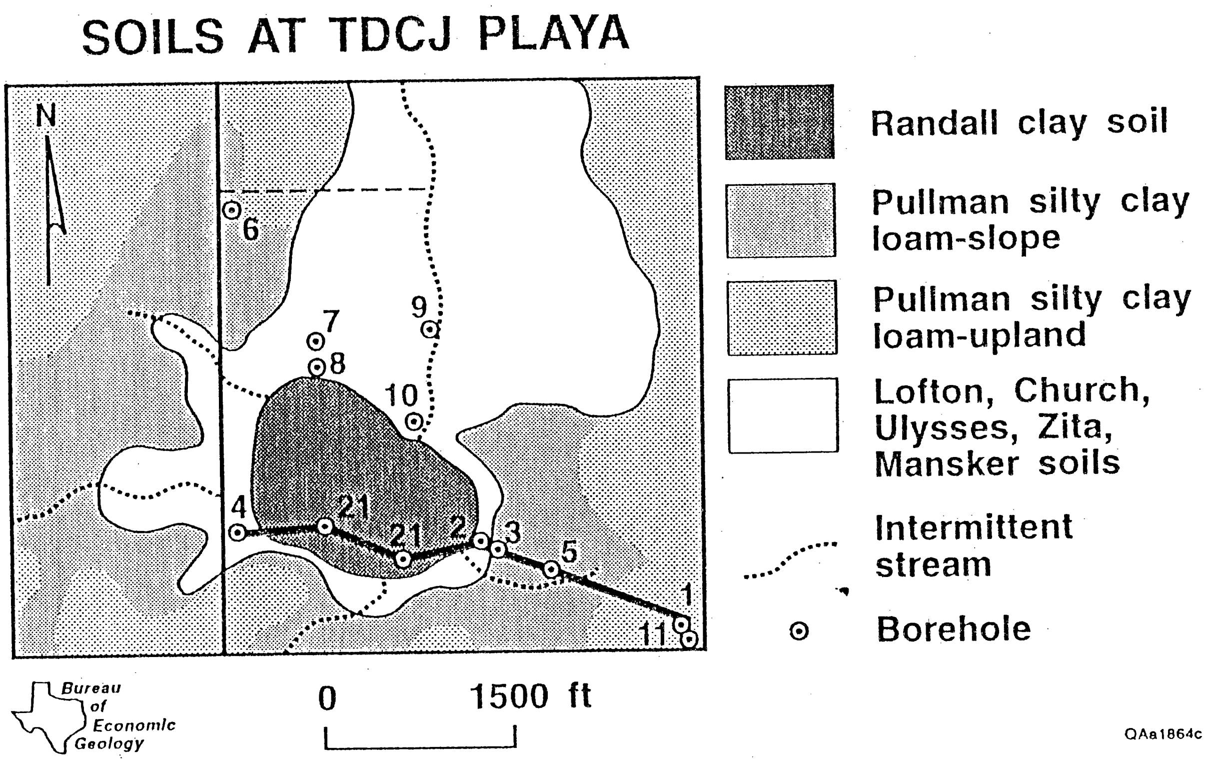

Figure 5. Soils map of TDCJ playa (modified from Jacquot, 1959), showing borehole locations.

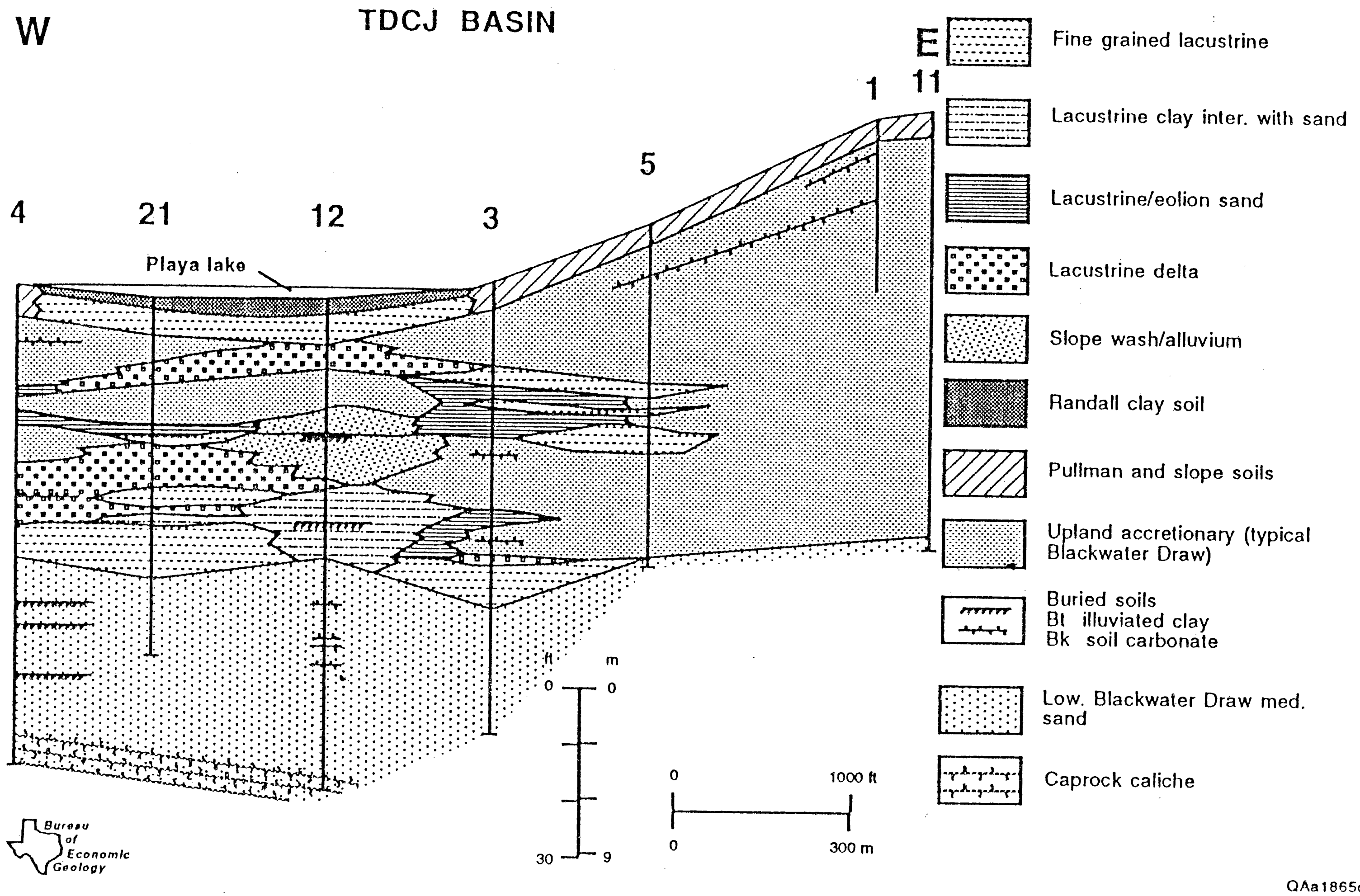

Figure 6. Stratigraphic section across the southern part of TDCJ playa basin. Abundant heterogeneous units identified as lacustrine delta complexes interfinger with lacustrine clays. Lacustrine clays can be traced in the subsurface south and east of the modern playa lake, indicating that the lake has episodically been larger. In other intervals, upland facies extend beneath the modern playa, indicating that the lake was smaller.

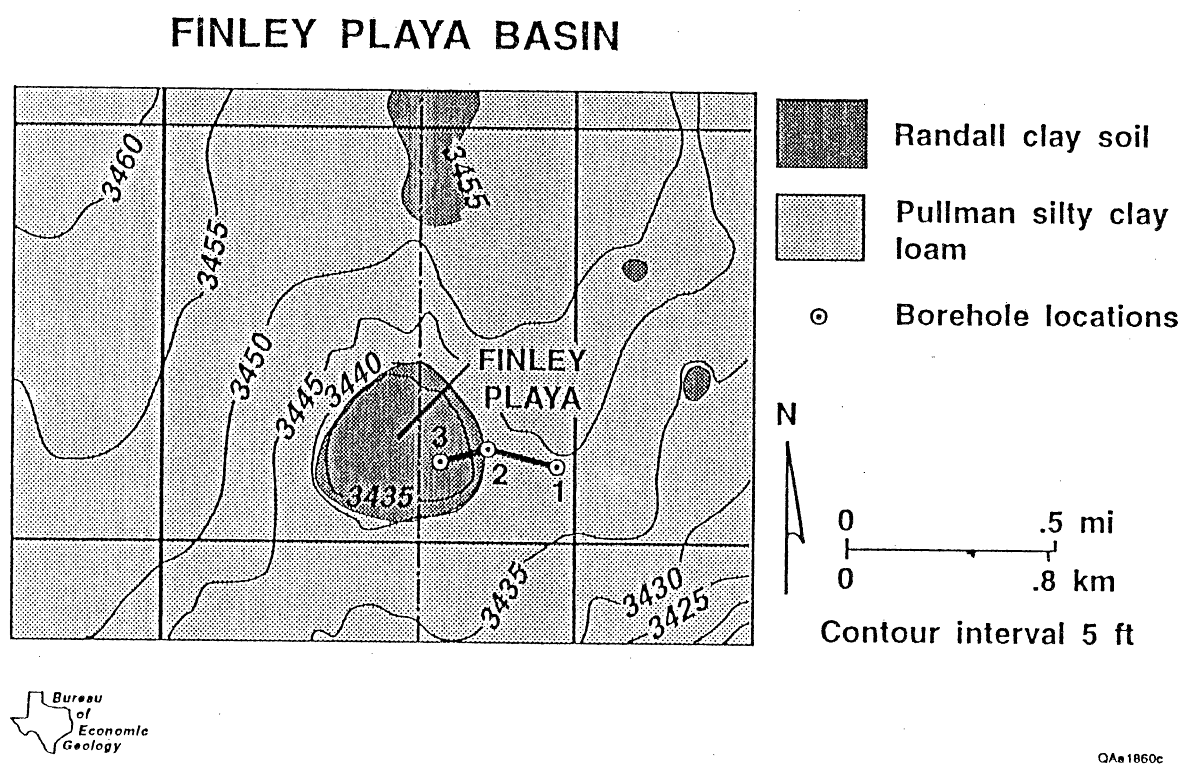

Figure 7. Soils map of Finley playa (modified from Jacquot and others, 1961), showing borehole locations.

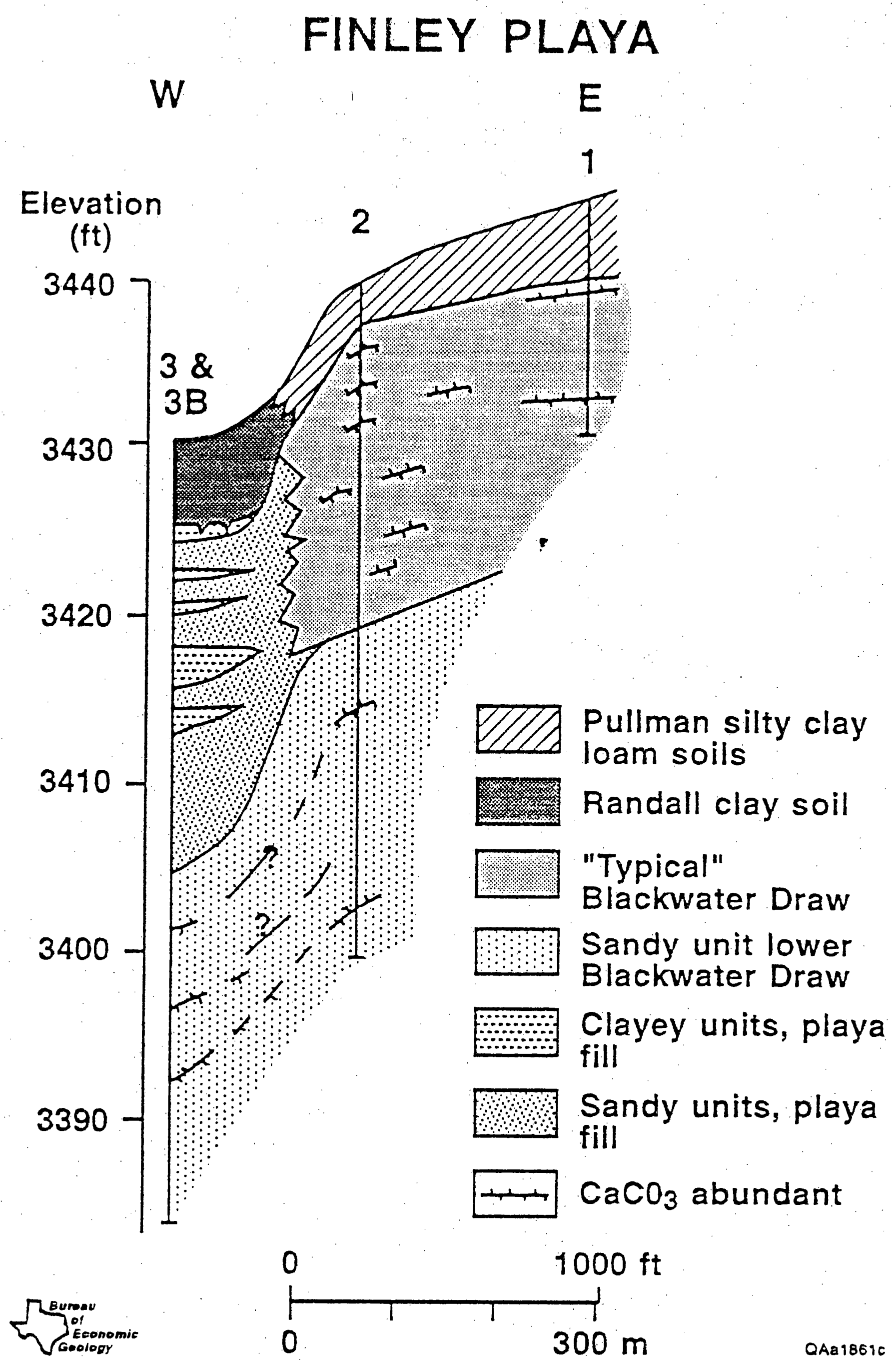

Figure 8. Stratigraphic section across the eastern part of Finley playa basin.